Hard Cutting — A Competitive Process ir

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The higher load carrying capacities, compact dimensions and longer life of hardened gears is an accepted fact in industry today. However, the costs involved in case hardening and subsequent finishing operations to achieve these advantages are considerable. For example, in order to achieve desired running properties on larger gears, it has been necessary to grind the tooth flanks. This costly operation can now be replaced, in many cases, by a new Hard Cutting (HC) process which permits the cutting of hardened gears while maintaining extremely low tooling costs.

At the heart of this new process are new types of tools with especially hard inserts that enable case-hardened gears to be finished on the same heavy-duty gear cutting machines used for cutting the gears in the soft. The rotating table and generating slide of the machine perform a stepwise generating movement for cutting the teeth into the periphery of the hardened blank. Fig. 1 shows the principle of the HC process. The number of working cycles depends on the number of cutter teeth. Each cycle consists of a generating, reversing and indexing movement.

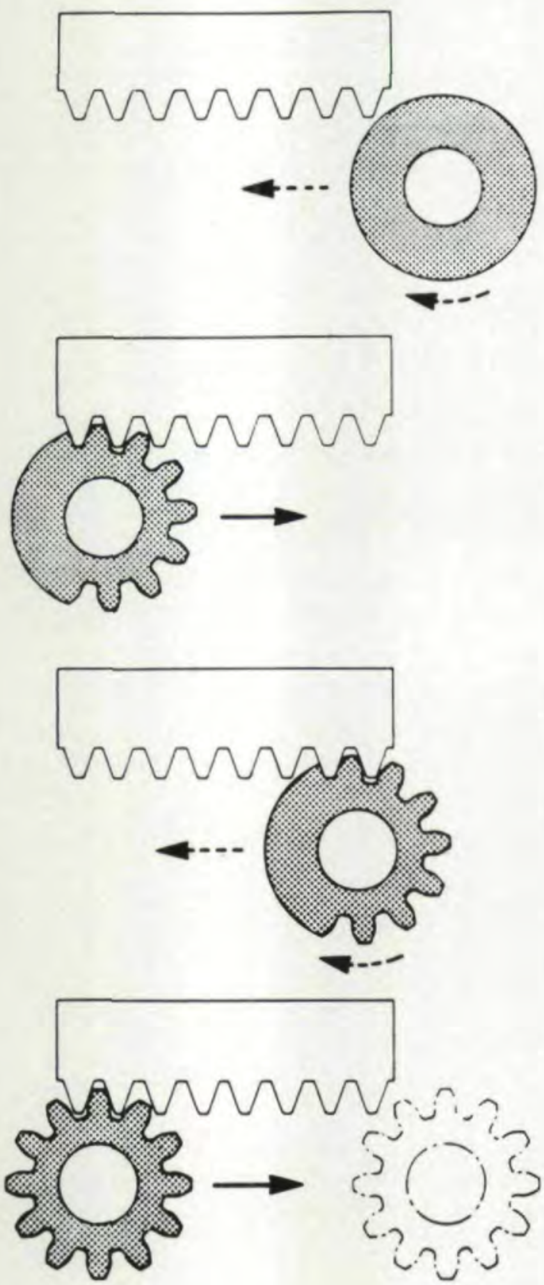
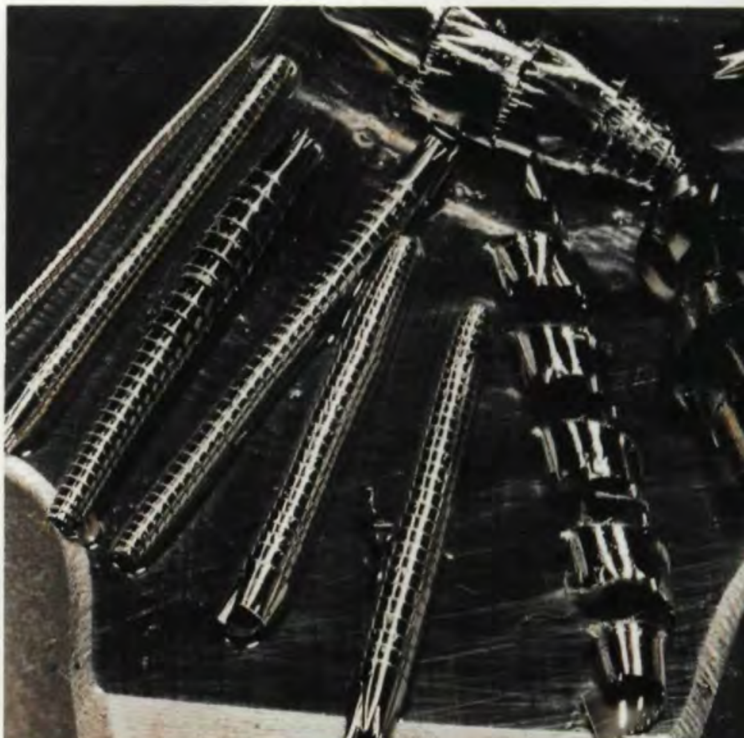


Fig. 1

Our experience indicates that AGMA 10 quality, coupled with a surface finish comparable to grinding, can be obtained with the HC process, replacing grinding for a wide variety of gears, including spur, single helical or narrow gap double helical design. When greater accuracy is required for turbine or marine propulsion drives, it can be obtained with a subsequent grinding operation. This grinding, however, is very



High Quality Gear Production

minimal since any distortion due to hardening has already been eliminated by the preceding HC process.

The tooling system is based on the single point tool. Such a tool is not restricted to a particular pitch and is, therefore, quite suitable for machining single gears. The cutting tool uses an arrangement of hard inserts on the body of the tool. Inserts consist of a 3 to 4 mm cemented carbide substrate to which a 1 mm layer of polycrystalline cubic boron nitride (CBN) is diffusion bonded. The main surface of the CBN layer forms the flank of the cutting edge, while the tool face is formed by the 1 mm thick edge of the CBN layer and the cemented carbide substrate. We see three major advantages result:

1. Hardened materials with a surface hardness up to HRC 65 can be accurately and cost-effectively cut because of the high mechanical and thermal shock resistance of the CBN tool material.
2. The advantageous arrangement of the insert means that regrinding is carried out on the narrow edge of the CBN layer, using diamond wheels to produce a perfectly sharp edge.
3. The design enables the tool to be reground on its face without affecting the profile, so that the tool can be utilized to its maximum without any sacrifice in accuracy.

Due to the tangential forces acting on the gear teeth during this process, high rigidity of the tool holder and machine parts is important. Because of this requirement, the machine used in the following tests uses hydrostatic bearing systems for the clapper box and ram guides, as well as hydraulic clamping on the rotating table and the generating slide during cutting.

Fig. 2

We recently conducted hard cutting trials on several large, but completely different gears and pinions. The specifications and tolerances for one of these test pieces are as follows:

Normal diametral pitch	1 DP
Number of teeth	23
Helix angle	20° 0′ 0″
Face width	9.0
Pressure angle	20°

Tolerance Type		AGMA Level	DIN Level
Profile:	4.000	14.5	2.6 (Ff)
Lead:	3.000	17.0	1.6 (Fb)
Pitch:	2.600	13.1	3.3 (fp)
Accumulated pitch error:	8.300	13.3	3.1 (Fp)

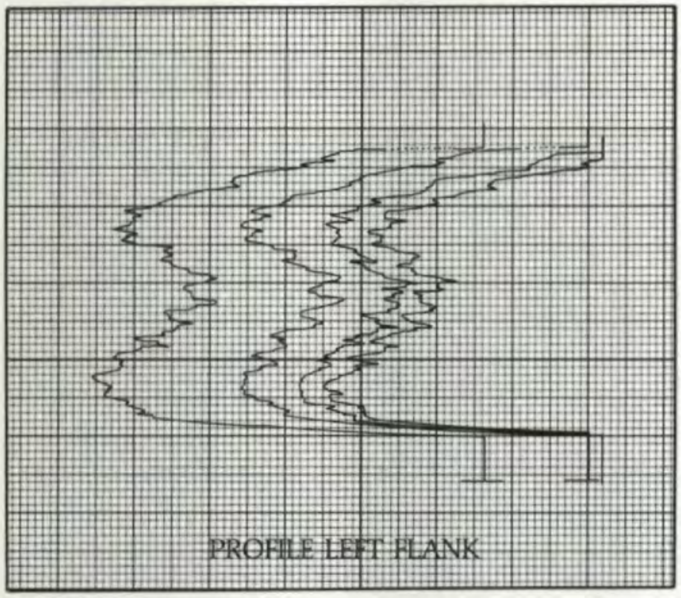
Note: Tolerances are specified in ten-thousandths of an inch. Surface finishes were in the 12 to 20 u range.

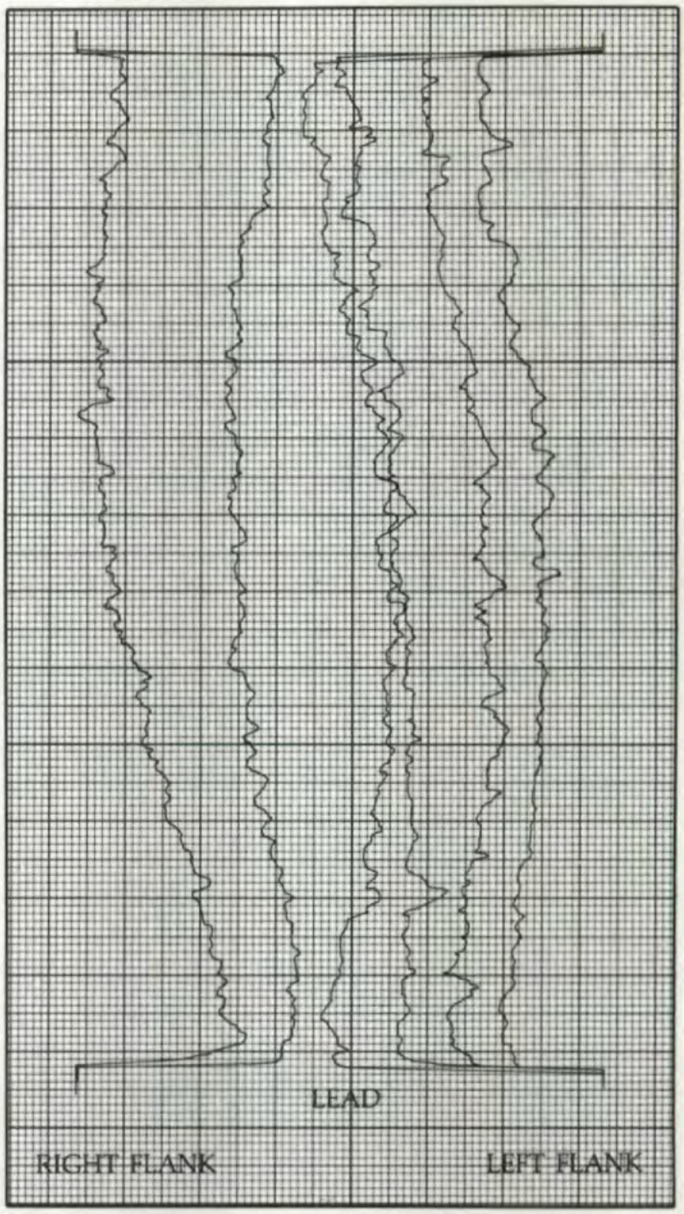
The test gear was cut by the single flank method. General setting data for all passes were

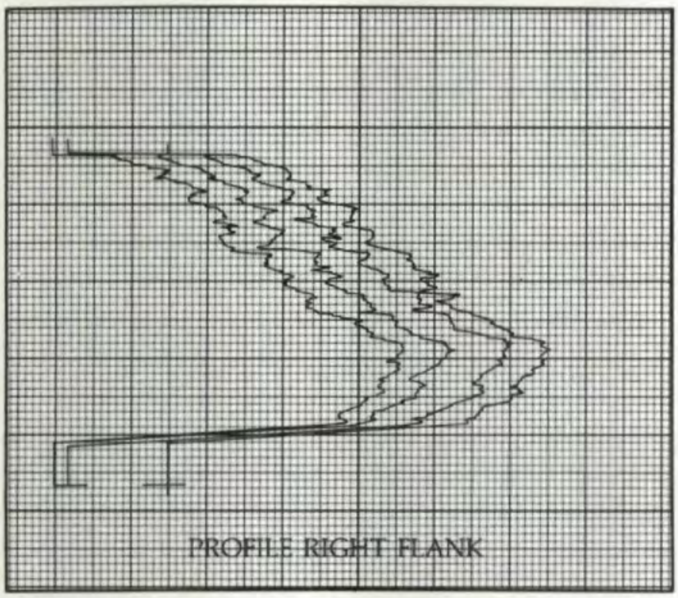
Ram stroke	13.4″	30 strokes/min.
Cutting speed		134 ft/min.
Generating path	2-2/3 pitches	
Cutter rake angle	−6°	

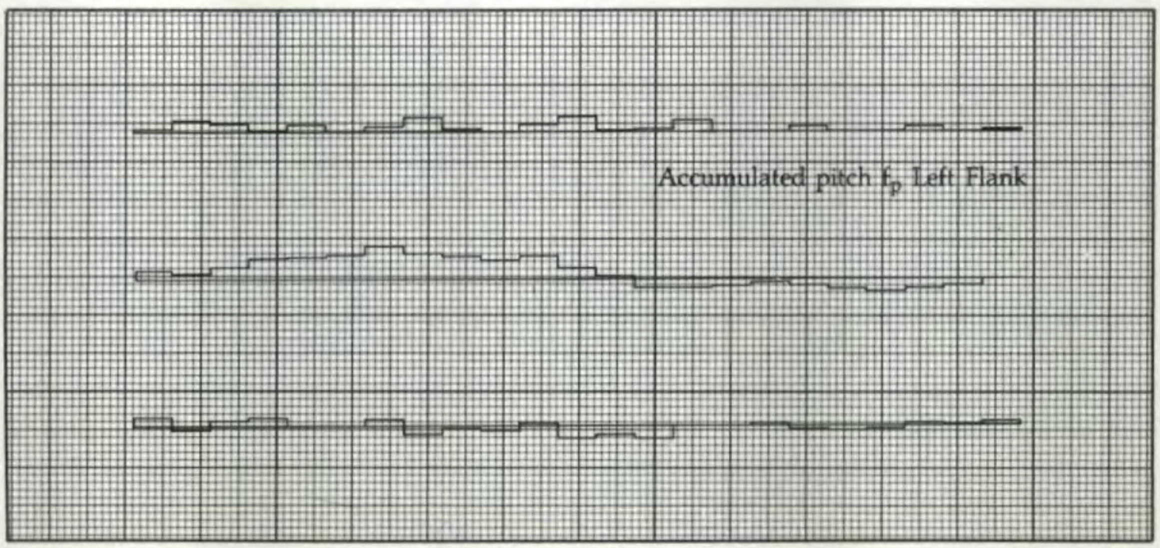
	L.H. Flank		R.H. Flank	
	Rough	Finish	Rough	Finish
Radial Infeed	.039″	.008″	.034″	.008″
Flank Layer Thickness	.0133″	.0027″	.0116″	.0027″
Total Strokes/Flank	104	88	104	88
(On Feed Setting)	(13)	(11)	(13)	(11)
Time per Flank	3.47′	2.93′	3.47′	2.93′
Indexing (Slow setting)	.60′	.60′	.60′	.60′
Total Time per Flank	4.07′	3.53′	4.07′	3.53′
Time per pass	81.4′	70.6′	81.4′	70.6′
Total Time per Gear	304 minutes			
Hardness of Test Gear	58 to 60 Rc			

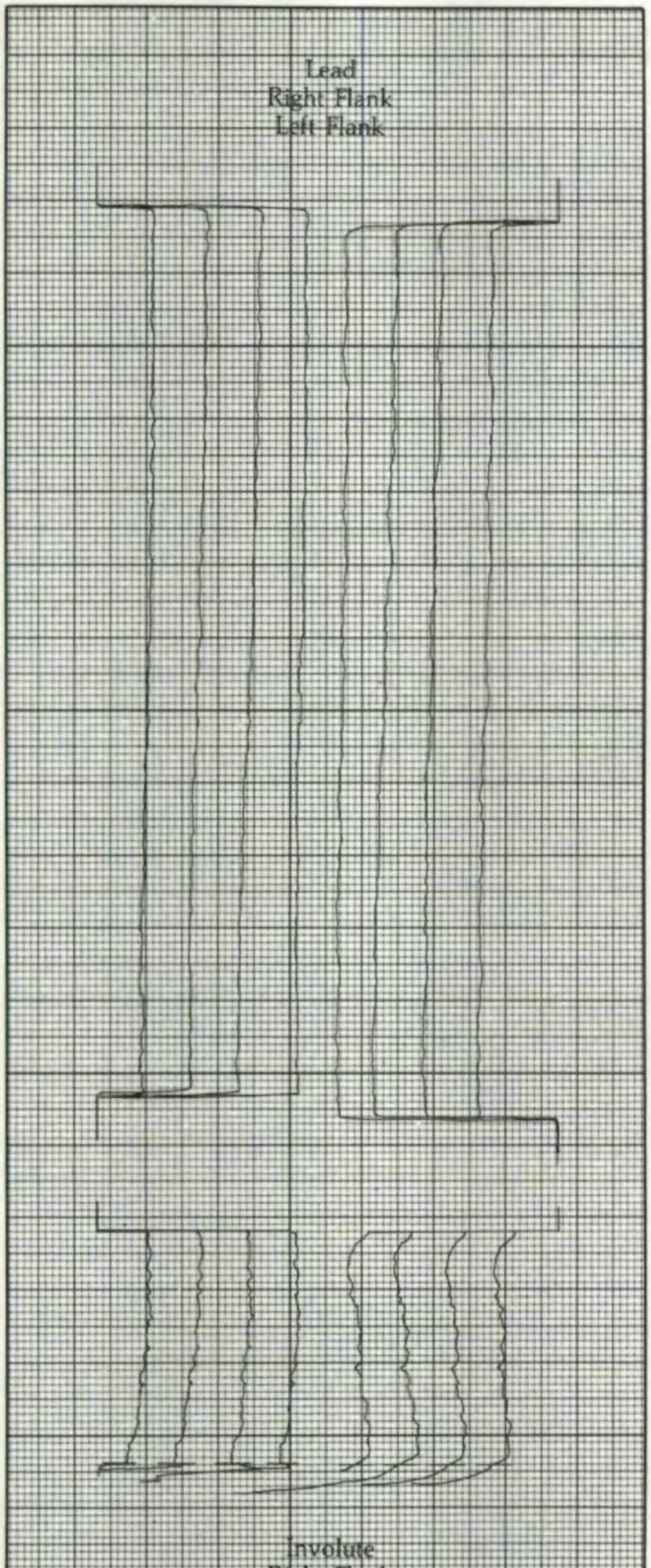
HEAT TREATED GEAR PRIOR TO HARD CUTTING PROCESS











FINISHED GEAR
AFTER HC PROCESS

The type of chip produced by the HC process is shown in Fig. 2. The tightly curled chips on the left are finishing chips and on the right are roughing chips. As our test samples show, .012"/.015" stock removal per flank per cutting pass is not unusual. The root fillet and diameter is not machined in this process; therefore, protuberance cutters should be used in the roughing or pre-heat treatment process.

Results and Conclusions

Our experience during these tests and in subsequent runs has shown that finishing times using the HC process are as much as nine times faster than traditional gear grinding methods. In many cases, it eliminates the need for a separate grinding step. It is important that the benefits of this process be recognized by gear designers as well as end-user applications engineers. The result will be new gear designs of compact dimension.

AUTHOR:

MR. ALBERT KLEIN *has nearly forty years of experience in the gear manufacturing industry. He received his early training with Hermann Pfauter Gear Hobbing in Ludwigsburg, West Germany, working with them until 1960. He has been with Horsburgh & Scott, producer of both custom gear designs and standard speed reducers, for 21 years.*